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THE EFFECT OF ROCKETS AND DISSYMMETRIC LOADS ON THE SPIN, BY "STATIC" MOMENTS

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16. Abstract

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The first topic taken up concerns the effect of rockets used as a rescue device from a spin; the study has up to now been limited to light planes; meanwhile, certain conclusions could be valid, at least qualitatively, for other types of airplanes, military ones in particular.

The second topic concerns the effect of an dissymmetric load on the spin of airplanes of all types: military, light or transport. The dissymmetry considered is a purely mass-related one such as could be due to fuel airfoil. Meanwhile, for military planes, the dissymmetry caused this time by external loads (whose dissymmetry is both weight and geometry related), is also taken into consideration.

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ANNOTATION

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THE EFFECT OF ROCKETS AND DISSYMMETRIC LOADS ON THE SPIN, BY "STATIC" MOMENTS

J. Gobeltz and L. Beaurain*

/18-1**

1. ANTI-SPIN ROCKETS

1.1. Introduction

The goal of this study was to find out if it is possible to use a rocket which can be rapidly installed on all light planes for a program of spin tests. In order to be acceptable, the rocket should not have prohibitive characteristics (especially too high a thrust)..

In the studies on scale models, the rockets have been given various orientations in order to define a direction of optimum effect; from the various results we retain here only the principal ones, that is, those which have been obtained with a rocket acting in pitch only, in roll only and in yaw only, respectively.

In addition to the intrinsic value of these results, the study has also permitted us to draw conclusions concerning the type of modifications that should be made in a light plane having a critical spin.

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** Numbers in margin indicate pagination in original foreign text.

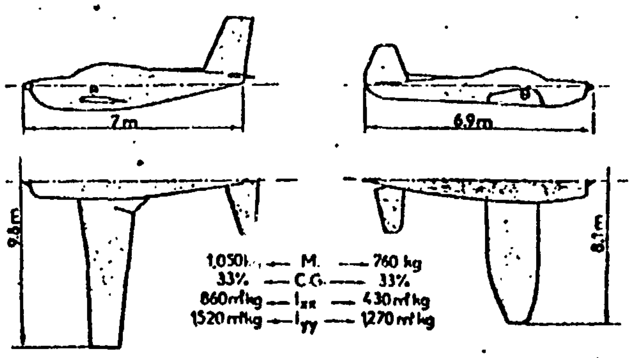

Figure 1. Models used (the dimensions are those of the actual aircraft).

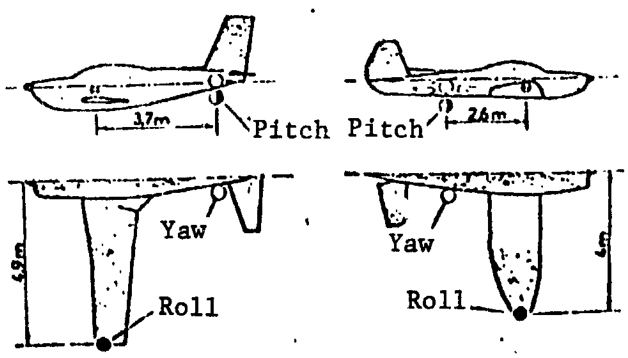

Figure 2. (Placement of the rockets to effect a pitch, roll or yaw).

1.2. Scale models used

Two models were retained for the study of the rockets; as Figure 1 shows, their characteristics, both in geometry and weight, are quite different. The models were freely modified with the aim of obtaining different types of spin, among these a flat, rapid spin; there is no reason to go into the problems that this spin raises (this, however, does not mean that all non-flat spins are automatically without problems).

The principle of the rocket engine used is the following: a fuse ignites a cake of powder, which modulates, depending on its chemical and geometric characteristics, the thrust and the operating time of the rocket. The gas emitted by the combustion of the powder goes through a tube to the place where we wish to apply the thrust (Figure 2 specifies these places). This solution allows us to place the motor block close to the center of gravity of the model, which then makes it possible to balance (trim) it.

Radio control apparatus is installed in the model; it provides for both the ignition of the rocket and the adjustment of the flap settings (complete or no adjustment, or in a predetermined manner).

1.3. Experimental conditions

/18-2

The effect of the rocket has been studied with different types of spin, most particularly with a flat and rapid spin (fuselage almost horizontal, 2 seconds/turn on the scale of the plane). Moreover, the results presented here are mostly those that were obtained with this type of spin.

After igniting the rocket, the flaps were set either to increase spin or recentered; flaps adjusted to increase spin is, of course, an unrealistic case, but it has the advantage of showing up the effect of the apparatus very well. With recentered flaps, for both models the spin was maintained, or almost so, without the rocket.

The characteristics of rockets that have been tried are variable over a wide range and included between the following extreme values (at the scale of the plane):

- a thrust of 8100 newtons acting for about 2 seconds;
- a thrust of 200 newtons acting for about 6 seconds.

These thrust values represent, respectively, 80-100% (depending on the plate), and 2-3% of the weight of the plane: in the first case, a value clearly prohibitive and not foreseeable for an airplane; in the second, a very weak thrust.

In the results that will be presented, it seemed desirable to give the thrust of the rocket in terms of the weight of the plane, and not of its module nor the moment that it creates. Let us note also that the results given are those which would be obtained with a moment arm as long as possible for a given plane, that is,

- for the roll rocket, the rocket is placed at the wing tip;
- for the pitch and yaw rockets, the rocket is placed at the extreme rear of the fuselage.

1.4. Results

1.4.1. Pitch rocket

It is evident that a rocket acting in the pitch mode is the most attractive solution because its effect is independent of the rotation direction of the spin. On the plane a single rocket should be installed.

Unfortunately, a pitch rocket is rather ineffective, at least if we stay within reasonable limits of thrust. In effect, by recentering the flaps, recovery is not possible with a pitch rocket except if the thrust is greater than 50% of the weight of the plane, and if it acts for 4 seconds or more. A thrust equal to 80% of the weight of the plane and acting for 2 seconds leads to an identical result. Such thrusts are not likely for a plane due to the problems of structural strength that such a rocket would present.

1.4.2. Roll rocket

At first we have studied if it is possible to pull out of a spin with a roll rocket regardless of the direction of its action, that is lowering or raising the wing. This result was obtained, but we have to specify that a rocket raising the outer wing (the wing which advances during the spin) is much more effective than the same rocket lowering the same wing, by a factor of 3:1.

If we take the most favorable direction of action (the rocket raising the outer wing) a roll rocket of the order of 10%

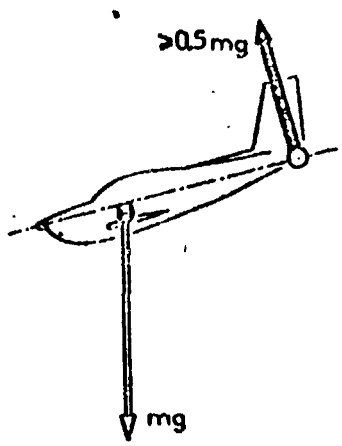

Figure 3. Rocket acting in pitch mode.

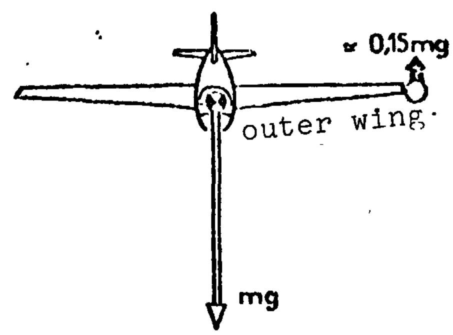

Figure 4. Rocket acting in roll mode.

of the weight of the plane and acting for about 5-6 sec. pulls the plane out of spin in about 3 turns, even if the flaps are maintained pro-spin. With an identical pulse, or almost so, the pull-out is better (faster) if the thrust is doubled. To nail down these ideas, let us say that the thrust of a roll rocket applied at the wing tip should be of the order of 15% of the weight of the plane in order to be sufficiently effective (see Figure 4).

If the recovery is made with a rocket raising the outer wing, this recovery is complete: moderate transverse see-sawing during braking, and diving movement bringing the plane to a vertical attitude. This is not the case if the rocket acts in the opposite sense (lowering the outer wing). In effect, stopping the spin comes about with transverse see-sawing, sometimes of sufficient amplitude to turn the plane upside-down. Recovery is effected, but only after maneuvers hardly unconventional for a light plane likely to disorient the pilot. Finally let us note as far as the rocket lowering the outer wing is concerned, that if its thrust is too weak, it can flatten out the spin momentarily, that is, approximately within the duration of its operation. The rocket can therefore have, depending on its characteristics, a pro-spin (weak thrust) or an anti-spin (strong thrust) effect. / 18-3

1.4.3. Yaw rocket

A very interesting effect is obtained with a very small thrust (2% of the weight of the plane) acting for about 7 sec with recentered flaps. In this case recovery is achieved in 5-6 revolutions; this recovery of course takes rather long but nevertheless only half as long as those achieved with recentered flaps without the rocket.

A thrust of the order of 5% of the weight of the plane and acting for 4-6 sec brings about recovery in 2-3 turns from a flat and rapid spin. Accounting for the characteristics of the spin from which the maneuver is made, a recovery in 2-3 turns can be considered a satisfactory result.

A yaw rocket is therefore very effective; another result characterizes this effectiveness very well: it consists of a rapid recovery (1-2 turns) obtained with a rocket of 12%, acting for 4 sec, flaps left pro-spin. In this case, the effect of the flaps becomes secondary with respect to that of the rocket.

1.5. Relative effectiveness of the rockets

Some of the results which will be shown show clearly that if we classify the rockets according to their effectiveness, we obtain the following order:

- pitch rocket (least effective)
- roll rocket
- yaw rocket

From the results of the study, by invoking the following parameters of the rocket:

- thrust modulus
- operating time
- moment arm
- recovery time,

we could define approximate effectiveness ratios between rockets; this ratio is:

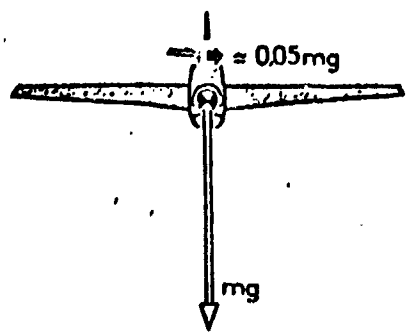

Figure 5. Rocket acting in yaw mode.

- about 15 between the yaw and pitch rockets;
- about 6 between the yaw and roll rockets (in this case the more favorable of the latter, that is, where the rocket tends to raise to outer wing).

1.6. Remarks on stopping the spin

Here we take into consideration certain difficulties that could arise in stopping a spin by means of a rocket. We limit ourselves to the case of the most effective rocket, that is, that acting in the yaw mode.

It is evident that if the apparatus were adopted to airplanes, it would be very desirable to control the operating time of the rocket. This time should be, in effect, adjusted based on certain parameters, the position of the rocket (lever arm), the type of spin to be overcome (which could not always be flat and rapid as was often the case in our tests), among others.

Let us examine here the case of a rocket with well defined and unmodifiable characteristics (such as a solid fuel rocket). It could well be that the effectiveness of the rocket would be too high, in the sense that the spin would be stopped before the rocket ceased to function. In this case, due to the effect of the rocket, we must fear inducing a spin in the opposite sense, or, in the case of upside down flight, going into an upside down spin. We can draw some conclusions on this topic from the following example:

At the L.I.F.M. we have already used the results on the rockets for the installation of such an apparatus on a certain airplane. The rocket chosen for this plane was solid fueled. Studied on the scale model of this plane, the rocket proved to be too effective if placed at the end of the fuselage (and acting in yaw mode, of course). In effect, with the flaps kept fully spin-supporting, the rocket brought about a very rapid recovery (= 1 turn) followed by a just as rapid onset of reverse spin. Note that the flaps remained unchanged, that is, they were now fully anti-spin, as far as the reverse spin was concerned, and it did not impede the latter to develop. Not being able to modify the characteristics of the rocket, we have reduced its effectiveness by reducing its moment arm. We have thus found an optimum position for the rocket such that its effectiveness should be sufficient to stop the spin and insufficient to bring about reverse spin.

We specify that this rocket acts for 4 sec and has a thrust / 18-4
equal to 20% of the weight of the plane. The result obtained with this rocket is in accord with those of the general study; in particular, its too high effectiveness, when it was placed at the tip of the fuselage, has not surprised us.

This example shows clearly that if, qualitatively, the conclusions drawn from this general study relative to rockets are valid for all light planes, when a certain rocket is considered for a particular plane, safety considerations require that the apparatus be subject to prior study on a model in a vertical wind tunnel, especially if the operating time of the rocket is not adjustable.

1.7. Considerations for geometric modifications

This section concerns the conclusions that can be drawn from the study of the rockets, conclusions relative to the type of modifications that should be made to certain airplanes with critical spin, in particular flat and rapid spin.

While in the windtunnel, we proceeded to the study of geometric modifications likely to improve the spin characteristics of a light plane; in general the foreseeable modifications to the plane are located at the rear; this can be shown by some examples:

- enlarging the fin (modification 1 in Figure 6);
- a keel (2 in Figure 6);
- enlarging the horizontal stabilizers (3 in Figure 6).

(The case of the parachute, however, is not a modification; it will be treated later on.)

If we look at these modifications relative to the rockets, we can see that in effect modifications 1 and 2 are of the same type as those of the yaw rocket, that is, a braking effect.

The effect of enlarging the horizontal stabilizers, on the other hand, is comparable to that of a rocket acting in pitch mode; that is, increasing the aerodynamic dive pitch moment.

By not taking into account the appropriate effect of the modification (that is, excluding all possible interaction of the modification with other elements of the plane), given the effectiveness ratios that exist between the pitch and yaw rockets, it is evident that an enlargement of the fin or the attachment of a keel is by far preferable to an enlargement of horizontal stabilizer area.

In the remark above we have excluded a possible interaction of such a modification with another element of the plane; by specifying it, we are thinking more of detrimental effects of increasing the horizontal stabilizer area, by lengthening the chord. In effect, for certain positions relative to the fin and the horizontal stabilizers, it can happen that the larger stabilizers mask the fin more which will cause it to lose effectiveness vis-a-vis damping the yaw. In the limit, the proper effect of the modification which is favorable can become secondary with respect to its detrimental effect on the fin. The result is therefore that the spin with modification is more severe (faster - therefore flatter) than that found with the original geometry.

As far as the increase of the fin area is concerned, it is necessary that this increase take place high up on the fin, that is, at the place where the modification has the greatest chance of being outside the slip stream of the fuselage and/or stabilizers. In effect, for an equal area, a keel (because it never interacts with another element) is often more effective than enlarging the fin.

In Figure 6 we have also shown a parachute; we can treat this case by considering that a priori its effect is of the same type as that of a rocket acting in pitch mode. From the results of the rocket tests whose effect the parachute simulates, its dimensions should be very great, which leads to possible problems of structural strength for attaching a cable to the plane. But an important remark is to be made on the subject of the attitude of the parachute during the spin. As shown in Figure 7, the cable is slightly inclined to the symmetry plane, such that a slight yaw component is created. Based on the effectiveness ratio of the pitch and yaw rockets, for the parachute the yaw component, even though very small with respect to that of the pitch, could also be effective, if not even more than the latter.

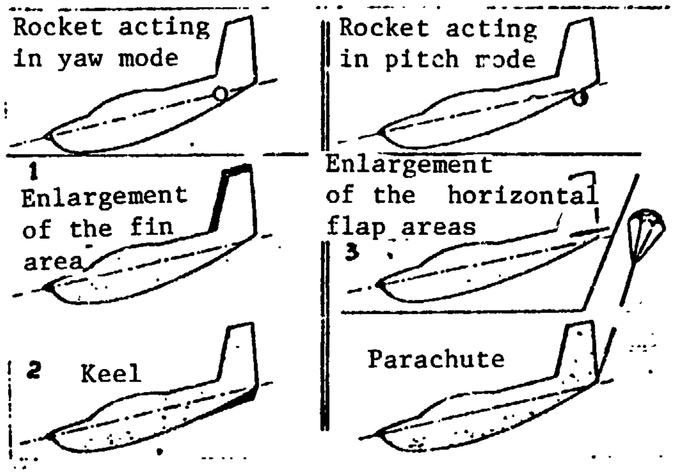

Figure 6. M̶o̶difications and devices

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Thus, as far as the parachute is concerned, its effect is only partially where we would a priori think it should be essentially, that is, in pitch.

These various remarks concerning the modifications and the parachute are generally valid for certain types of critical spin: smooth spin with predominant yaw velocity. This is often the case in critical spins of light planes. If we consider other types of incontrollable spin (but which generally do not occur with light planes) such as very rough phenomena or problems of deep stall, the preceding conclusions have no value. In particular, for deep stall characterized by remaining at stalled incidence even in the absence of spin rotation, it is evident that the choice of the rescue system should be the parachute or a pitch rocket, and that their characteristics (dimensions of the dome for the parachute or the module for the rocket) will depend on the seriousness of the problem. As far as the very rough phenomena are concerned (of importance mostly for military planes), the use of a rocket seems to be sensitive;

even the choice of the thrust direction is not evident.

1.8 Conclusion

From the results obtained in the study of rockets on models of light planes, we can conclude that such a device is very likely to be a rescue system from spin. The characteristics (thrust, duration and hence momentum) are acceptable and such that they should not present any difficulty in installing the device on a plane, it being well understood that the rocket should act in yaw mode.

A rocket with controlled operating time is very desirable; a rocket with fixed operating time can also be considered, but it requires taking some precautions, in particular, before its use on a given plane, it should be the object of a study in a wind tunnel on a model of the plane.

In a more general vein, certain conclusions of this paper could be valid, at least qualitatively, for other types of airplanes, for example military ones, especially if the critical spin should be free from roughness: a flat and rapid spin, for example. For these planes we believe that a rocket acting in the yaw mode is still the best solution. In effect:

- on military planes, we could rule out flat and rapid spin by means of a vertical keel (whose effect is of the same type as that of a yaw rocket);

- the geometry of current military planes is such that a yaw rocket can have a moment arm longer than a roll rocket; this is an additional argument in favor of the yaw rocket.

It is, however, evident that these hypotheses should be verified by tests on scale models in a wind tunnel. Such tests should result in more quantitative conclusions.

2. EFFECT OF A LOAD DISSYMMETRY ON SPIN

2.1. Introduction

In a study of spin made in the vertical wind tunnel on a given plane, it is customary to study the various geometry and weight parameters in order to better cover all of the possible conditions of the plane; meanwhile, as far as the position of the center of gravity is concerned, for a long time only the longitudinal position has been taken into consideration, and to a lesser degree, its location along the vertical.

At the L.I.F.M. a study of a general character has been undertaken in order to define the effect on spin of the lateral position of the center of gravity. The study has considered mostly a displacement of the center of gravity caused, for example, by fuel in the airfoil. It therefore consists of a purely weight-related load dissymmetry. Meanwhile, for military planes we also take into account the effect of a lateral decentering caused this time by external loads whose dissymmetry is both geometry and weight related. This report gives the principal results of this study. /18-6

2.2 Experimental conditions

About 25 models of planes of all types (military, light, transport) have been retained.

The lateral decentering that we have considered on these models is often between:

- 4-12% if we relate them to the average aerodynamic chord;
- 1-2% if we relate them to the wing span (see Figure 8); (some of the decentering was greater than these values).

As shown in Figure 8, the dissymmetries represented in the models are, at least for some of them, less than the maximum dissymmetry likely for the plane.

The study has been limited to upright spin; for the majority of the models tested, the tests have been carried out with the center of mass displaced successively:

- toward the outer wing (wing that advances during the spin);
- in the plane of symmetry;
- toward the inner wing

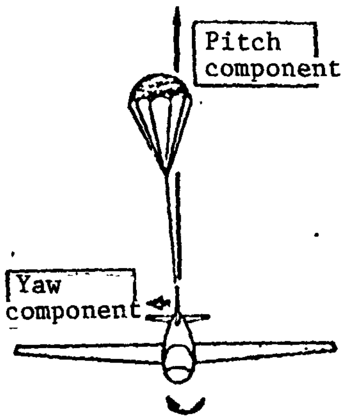

Figure 7. Attitude of parachute during spin

2.3 Results

2.3.1. General aspect

In the limits that were studied, the effect of a weight dissymmetry is widely variable: from none to great, depending on certain test conditions. In the meantime, we have to specify that while the effect is not zero, it is almost always in the same sense for all of the models tested. The only exceptions to this remark are two cases for which there is a reversal of direction of action; this reversal finds its explanation in the roughness as we will see later on.

As shown in Figure 9, there is an effect:

- pro-spin when the center of mass is displaced toward the outer wing;

- anti-spin, center of mass toward the inner wing.

The effect of lateral decentering is manifested by various means:

- across the range of the flap settings for which the spin is maintained (and consequently, the chances for recovery);
- on certain characteristics of the spin: longitudinal and transverse attitudes and rotation velocities, as well as roughness.

These points are taken up in detail in subsequent sections.

2.3.2. Effect on the range of spins

According to Figure 10, the effect of a load dissymmetry is:

- None in about 20%)
- Small in about 25%) of the cases studied
- Moderate in about 35%)
- Great in about 20%)

The effect of the weight dissymmetry is therefore variable; this depends partly on the decentering which is not the same for all the models, but also and above all, on other parameters such as the type of airplane (light, military, transport); the specifics will eventually be given on this subject.

Figure 10 shows that relative to a symmetric load, the range of flap settings within which the spin is maintained is greater / 18-7 when the center of mass is toward the outer wing; the reverse is observed when the center of mass is displaced toward the inner wing.

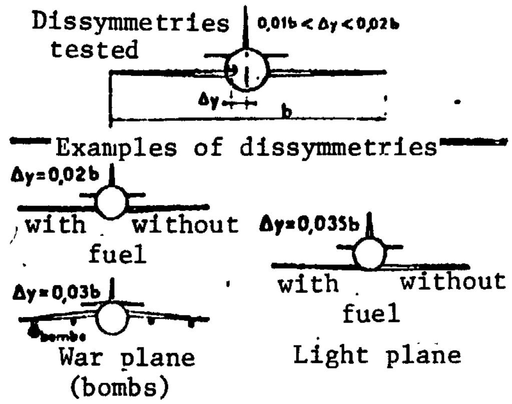

Figure 8. Dissymmetries considered and likely dissymmetries for certain types of aircraft.

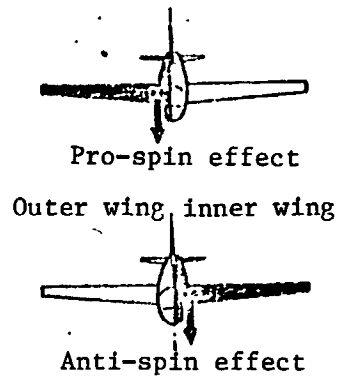

Figure 9. Effect of a load dissymmetry.

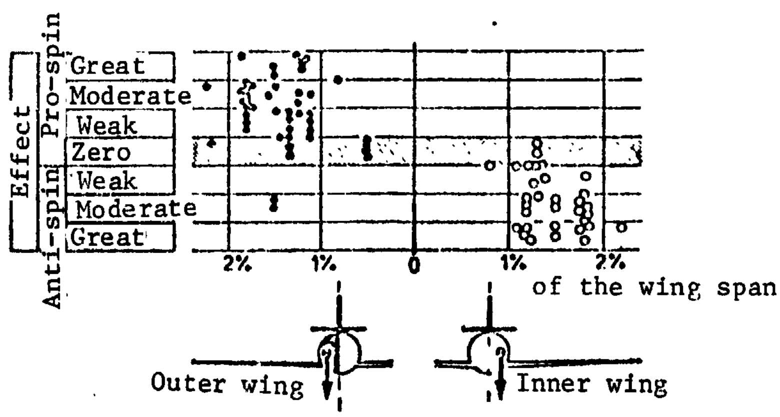

Figure 10. Effect on the spin ranges

As an example, for a model for which the effect has proved to be large, this effect is characterized in the following manner (see Figure 11):

- with symmetric load, the spin "perpetuates itself" for half the range of the flap settings;

- with the center of mass displaced toward the outer wing, the spin is maintained, or maintained longer, for almost all of the flap range; pulling out therefore becomes very difficult;
- with the center of mass toward the inner wing, there is almost no spin maintained.

For certain planes, and this is our first conclusion, the lateral position of the center of mass is among the parameters which most affects the spin. In the limit, it can be most effective at a point such that, for example, the effect of the flaps becomes secondary. In any case, for certain planes such a lateral displacement of the center of mass clearly has a greater effect than even a longitudinal displacement.

2.3.3. The effect on certain spin characteristics

We now study the effect of the lateral decentering on certain spin characteristics; we omit for the moment the effect on roughness.

We can expect that initially a dissymmetric load affects the transverse attitudes; this is true but only moderately so, since in our tests the variation of the transverse trim has rarely exceeded 10%, even though certain decentering shifts that have been made have been large.

In effect, lateral decentering modifies the equilibrium of the spin, so that its effect is more obvious on characteristics other than the transverse trim. We want to talk about the longitudinal attitude and the rotation velocity (these characteristics are, moreover, often related, since a change in the rotation velocity, by its effect on the centrifugal pitch moment, modifies the longitudinal trim).

In Figure 12 we see that a lateral decentering equal to 1.5% of the wing span, <u>on the average:</u>

- when the decentering is pro-spin, the spin is faster by 20% and there is less dive by 15°;
- when the decentering is anti-spin, the spin is slowed by 15% and there is more dive by 15°.

But these are only average values of all the results. Now certain values can be far removed from these average values. As an example, the rotation velocity can vary by 40% and the longitudinal trim by 30° or more. Thus, and still as an example, under the effect of a pro-spin lateral decentering a spin with average dive and speed with symmetric load can become flat and rapid; that is, the fuselage is horizontal or practically so, and at ≤ 2 sec/turn (at least for military and light planes) with dissymmetric load.

In general, for a given plane, the spin is even more difficult to overcome with the flaps if it is flat and rapid. In other words, the range of flap settings for which the spin is maintained is greater as the spin becomes faster and flatter. This remark provides, at least for certain planes, an explanation for the extension of the spin window which has been seen before (see Section 2.3.2.) /18-8

From these results we see that a dissymmetric load can induce a flat and rapid spin which would not exist with a symmetric load; in addition to problems of recovery, this spin can bring about centrifugation problems for the pilot. This is the case for a large number of military planes where the pilot is located relatively far in front of the center of mass, and where in a well formed flat and rapid spin, the axis about which the plane turns passes approximately through the center of mass of the plane.

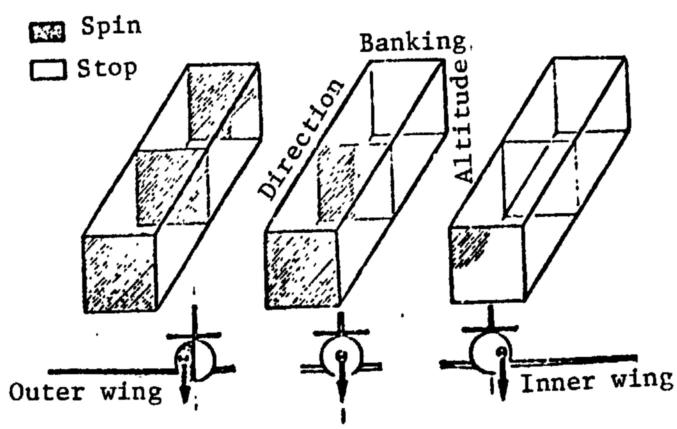

Figure 11. Example of a great effect.

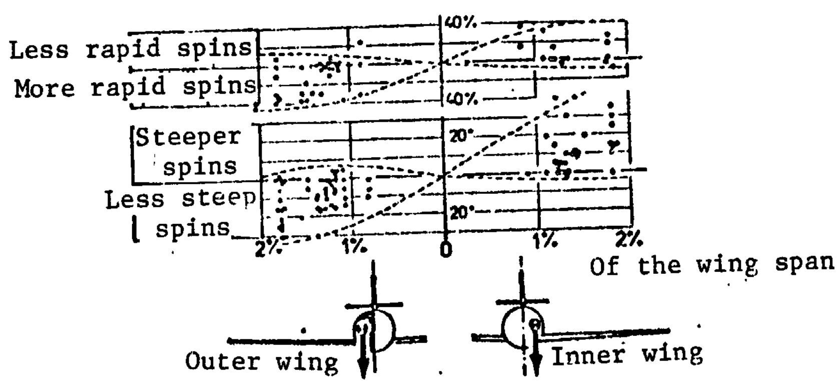

Figure 12. Effect of the longitudinal attitude and on the rotation velocity.

2.3.4. Effect on roughness

In a general manner:

- the spin of a light plane is smooth, that is, free from roughness;
- the spin of a transport plane is smooth or moderately rough;
- the spin of a military plane can be smooth, or at the other end, very rough. A plane can, moreover, have different types of spin. When the spin is very rough, the agitation can have an amplitude sufficient to transform a spin into

another stalling phenomenon: barrel roll (rotation about the toll axis), small upside down transverse or longitudinal see-sawing, or even disordered maneuvers.

In Figure 13 we see that if, with symmetric leads, the spin is smooth or not very rough, it remains smooth or not very rough with dissymmetric loads regardless of the decentering direction. This is shown in the figure for light planes, and also, in a less marked manner, for transport planes.

For the military planes, the effect of a lateral decentering can be felt on the roughness; thus, when the center of mass is displaced toward the outer wing, spins with divergent agitation are more frequent than with symmetric loads. Conversely, with the center of mass displaced toward the inner wing, the phenomena are systematically smooth or not very rough.

There is reason to expound on this point.

Decentering toward the outer wing has, as we have seen above, often a pro-spin (pro-rotation) effect. But it has come up in this section that this decentering can also have a pro-roughness effect, and these can, in the limit, become divergent.

Now it happens that the pro-roughness effect prevails over the pro-rotation effect. The maintained spins therefore become less numerous than with symmetric loads. This explains the existance of two peculiar points included in Figure 10 for which the direction of the effect of decentering toward the outer wing is not the same as that in the other cases. For these two points there is less spin because the roughness is more frequent and of higher amplitude, which acts to stop the spin. We can nevertheless confirm for these two points that if it weren't for the roughness, the effect of decentering would be the same as for the other models.

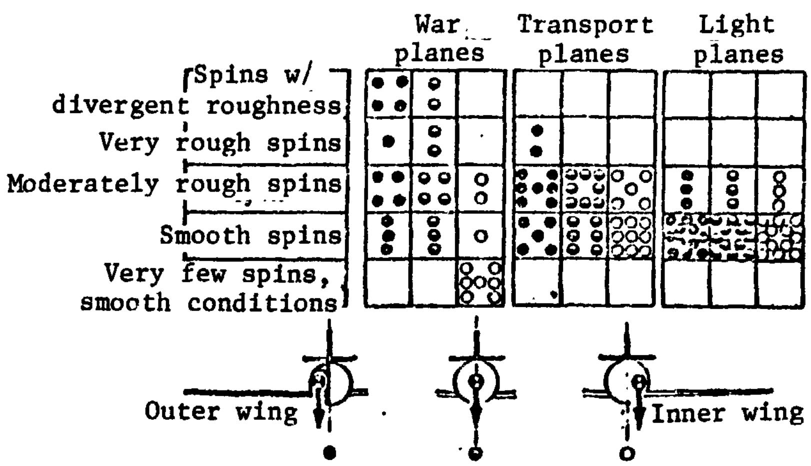

Figure 13. Effect on roughness

Again for the military planes, but this time with the center of mass toward the inner wing, according to Figure 13 it seems that for any model we have not encountered very rough phenomena, and yet spin is frequently stopped. The effect of decentering here is effectively a pro-braking and not a pro-roughness effect.

From these results on military planes, we can expect that for a given plane there could exist a lateral decentering optimum for the maintenance of spin, and this decentering could vary depending on the plane, the modulus, of course, and also the direction. In effect, in the case where, with symmetric loads:

- the spin is fairly smooth, the decentering is optimum when the center of gravity is toward the outer wing;
- the spin is very rough, the spin could be better maintained when the center of gravity is toward the inner wing; the lateral decentering modulus would therefore be both suffi[illegible] to smooth out the spin and insufficient to stop it.

In conclusion of this section, like all rules, that concerning the effect of load dissymmetry involves exception; in this case the exception is called roughness.

2.3.5. Effect of the plane type

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In the preceding sections, the results have been obvious on certain points: the effect of mass dissymmetry, depending on the type of plane. This section covers other specifics on this topic.

As is shown in Figure 14, the effect of lateral displacement is more or less marked, depending on the type of plane:

- an effect often great for military planes;
- an effect moderate, on the average, for transport planes;
- an effect often weak if non-existant for light planes.

Now we have to note that the main flap:

- for a military plane, is often the banking control;
- for a transport plane, is, depending on the plane, the banking or the direction control;
- for a light plane, often the direction control.

Taking these remarks into account, it seemed interesting to analyze the effect of a load dissymmetry by taking the main flap into account.

We have thus obtained results which are shown in Figure 15, from which we see that:

- in 90% of the cases where the banking is the main control flap, the effect of lateral decentering is moderate or, most often, great. The percentage would be 100, if it weren't for two peculiar cases (spins with divergent roughness), which have been considered in the preceding section.

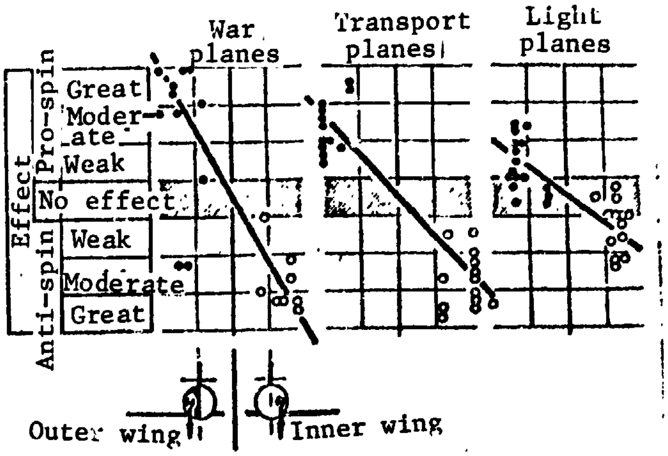

Figure 14. Effect as a function of plane type.

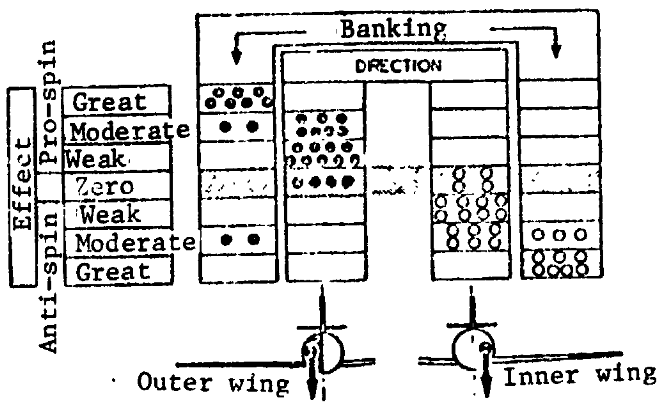

Figure 15. Effect as a function of most effective flap type.

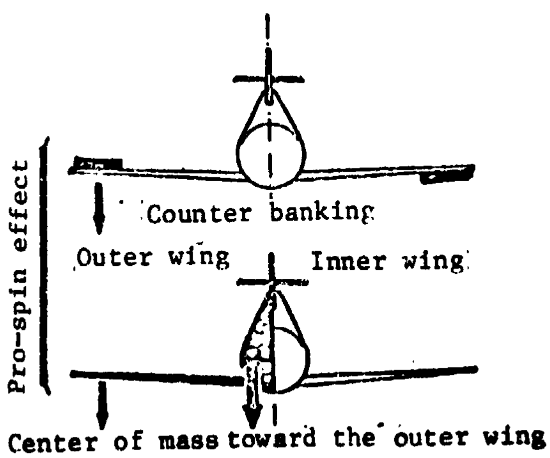

Figure 16. Comparison between the effects of decentering and of banking.

- in 70% of the cases where the direction is the main flap, the effect of decentering is weak or non-existent, it is never great.

A case which appears in Figure 14 confirms these remarks: it is a military plane which is the only one among those that we studied for which the flap having the most effect on the spin is the direction. For this plane the effect of load dissymmetry has proven to be weak or non-existent.

The effect of a decentering is therefore more a function of the main flap than a function of the type of plane.

REMARK: It happens sometimes that the main flap for the spin of a plane is the altitude control. This case has not come up in any of the models chosen for this study. This explains why in this section only the direction and banking control were taken into consideration.

2.4 Effect of dissymmetric external loads

By external load we mean here heavy, not light, loads of the type: empty tank. This of course does not include military planes for which the effect of a purely load-related dissymmetry is often great.

From the results of tests carried out with dissymmetric external loads, it so happens that very often a load under the outer wing has a pro-spin effect. Conversely, a load under the inner wing has a pro-spin effect. Conversely, a load under the inner wing favors recovery.

The results are therefore at least qualitatively of the same type as when the center of mass is displaced toward a given direction, whether the decentering is caused by an internal or an external dissymmetry. We can also conclude that in the case of external dissymmetric loads, the effect of the geometric dissymmetry is secondary with respect to that of the mass dissymmetry. /18-10

2.5. Relation between the effect of lateral decentering and the effect of banking

When, for the spin of a plane, banking is the main flap:

- counter banking, that is, set against a turn in the same direction as the spin, favors the maintenance of the rotation, for all the cases where the phenomena are not very rough. Counter banking has, therefore, a generally pro-spin effect.

- in supporting banking, often the spin slows and stops, even in the absence of roughness.

It seems as if we could draw a parallel between the effect of banking and the effect of a dissymmetric load, vis-a-vis the spin. Thus, if we consider the effect of the two parameters on, for example, the point concerning transverse equilibrium, we would have to say that (see Figure 16):

- on the one hand, counter banking
- on the other hand, the center of gravity displaced toward the outer wing.

both have the same effect, since they tend to lower the wing that advances during the spin.

The ailerons (geometric parameter) and the decentering (mass parameter) should therefore have an effect of the same type on the transverse attitude, and, as seems to be confirmed in this study, consequently on the overall phenomenon. This could explain why the effect of decentering should be more marked when, for a spin of a plane, the main flap is banking.

Along the same lines, we could also specify here certain results which were obtained in those tests that have been the topic of the first part of this report, that is, tests on models equipped with rockets. It is the case of rockets acting in the roll mode.

We have seen in Section 1.4.2 that a rocket, sufficiently powerful, can ruin the equilibrium of the spin, and stop it even when the direction of the action of the rocket lowers the outside wing. But we have also seen that in this direction of action, if the thrust of the rocket is relatively weak, the rocket has the effect of flattening the spin, at least momentarily, that is, during the operating time of the rocket. This then could have a pro-spin effect, when, we repeat, it tends to lower the outer wing. If we now repeat several conclusions here, we find that lowering the outside wing:

- either by banking
- or by load dissymmetry
- or with a rocket (of relatively weak thrust)

leads to the same result, that is, it favors the maintenance of spin.

2.6. Conclusion

From the study of the effect of the load dissymmetry on the spin of planes of all types, various conclusions can be drawn:

1. The effect of load dissymmetry (purely mass type) can vary from none to great, depending on the type of plane, among others. But when this effect is not zero, it is practically

always in t he same sense, that is, when the center of mass is displaced toward:

- the outer wing, the effect is pro-spin, that is, it increases the range of flap setting within which the spin is maintained;
- the inner wing, the effect is anti-spin.

2. The pro-spin effect can signify, furthermore, the onset or the increase of the likelihood of flat and rapid spin, during which, for certain planes, the pilot would be subject to uncomfortable if not unbearable acceleration.

3. The effect of a lateral decentering is more marked in planes whose main flap for the spin is banking, or banking being the main one: /18-11

- is most often the case for military planes
- sometimes the case for transport planes
- rarely the case for light planes.

4. Decentering due to an external load under a wing has the same direction of action as the decentering toward the same wing produced by internal dissymmetry.

5. In the case of very rough phenomena, the effect of lateral decentering toward the outer wing can be diminished, cancelled or even reversed in direction by an increase in the roughness, which can then lead to a recovery but always by means of diverse phenomena, for example barrel roll or even inverted flight.

In a general conclusion, we have to mention above all that the center of mass shifted out of the plane of symmetry can be classified among the parameters which affect the spin the most. In the limit, its effect can be even more important than that of all other, mass-or-geometry-dependent parameters. Also, it is necessary that this parameter be taken into consideration in all test programs on spin, either in a windtunnel or on the airplane itself.